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ABSTRACT

Five methods for studying the process of reading a text are presented, and a model for discourse processing is outlined. Discourse processing refers to comprehension of the meaning underlying the verbal message. The methods discussed here investigate the reading process as it occurs, and focus on the amount of time taken to complete a task or function. They include paragraph reading time, sentence reading time, word reading time, eye movement recording, and the use of a reader-controlled text window on the computer screen to measure reading speed in relation to text type and structure. Advantages and disadvantages of the methods are noted. Four concepts needed to analyze discourse processing are defined, including semantic coherence, theme-rheme structure, subject-matter knowledge, and reading purpose. Then the process of discourse comprehension is outlined, with reference to four types of coherence: referential, within-sentence, topical, and functional. Five hypotheses concerning the processing of specific discourse structures are proposed. A 16-item bibliography is included. (MSE)

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THE ON-LINE INVESTIGATION OF READING A TEXT: METHODS AND A MODEL[1]

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ABSTRACT

In this paper, five methods for studying the process of reading a text are presented, and a model for discourse processing is outlined. The model views the process as reader-text interaction, where the immediate processing of text is controlled by textual coherence (within-sentence, referential, topical, and functional), combined with reading strategy and reading purpose.

1. Introduction

The psychology of reading has become a field of scientific investigation which attracts researchers from various scientific disciplines. This is reflected in the growing number of studies published in the last decade (see Weintraub et al. 1982). The increased interest in exploring the reading process can be seen as a consequence of two circumstances:

(1) An adequate reading skill is a necessary prerequisite for coping with the growing body of written information in present-day society. This

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has lead to the adoption of the concept of 'functional illiteracy'. It refers to cases where the reader cannot comprehend what he is reading, in spite of having obtained a skill of encoding graphic symbols into words. In other words, a functionally illiterate person is unable to acquire information from written texts.

(2) Cognitive psychology, which deals with human information processing, has developed into a dominant paradigm in the field of psychology, especially in experimental psychology. The process of reading is an obvious subject matter for this information-processing psychology.

In addition to psychologists, the exploration of discourse processing is becoming increasingly popular among researchers in text linguistics and educational science.

Consequently, there is a practical need for scientific knowledge concerning the reading process; in addition there exists a promising scientific framework for investigating it.

The present paper focuses on discourse processing. 'Discourse' is usually taken to mean a body of coherent information that is communicated either orally or in writing. Discourse processing entails the comprehension of the meaning underlying the verbal message of the discourse. In this paper the term 'discourse' refers to written messages only.

Basically there are two different ways to study discourse processing. Firstly, one may study the end product of the process, i.e., the memory representation. A second approach is to monitor the process "on line". Memory studies can be carried out by asking the reader to recall the text after he has finished reading it, or by presenting him with certain aspects of the text for recognition, or by asking questions about the content of the text.

A number of methods can be employed to monitor discourse processing on line. Five of them are introduced in the following.

2. On-line methods in the study of discourse processing

All on-line methods are based on the idea of mental chronometry. The idea is firmly established in the area of experimental psychology. It is founded on the fact that any kind of information processing takes place in time. Consequently, conclusions about processing can be drawn from the time expended on a task. To give a simple example, it takes less time to add 5 and 2 than to add 7 and 2. So it can be concluded that the former addition is performed more easily.

A second essential characteristic of on-line methods is that they make the simultaneous tracking of the reading process feasible. In other words, by applying an on-line method, the researcher is able to monitor the processing of a written text as it is going on.

A third characteristic feature of on-line methods is that the researcher is not forced to tamper with the on-going process in order to collect data. The obtrusions I am refering to usually appear in the form of subsidiary tasks unrelated to normal reading. Reacting to an auditive signal, continuous question answering and filling up missing words are examples of such tasks.

On-line methods for studying discourse processing can be divided into five categories:

2.1. Paragraph reading time

As the name indicates, this method involves measuring the reading time for an entire paragraph of text. It is a relatively crude procedure of monitoring the on-line comprehension of discourse, because it is unable to reveal any characteristics of reading process inside the paragraph.

Thus Britton, Meyer, Simpson, Holdredge and Curry (1979) could not find any evidence that the semantic macrostructure of the text affects immediate processing. Britton et al. included the same paragraph in two different texts. In one text the target paragraph was positioned high in the content hierarchy, that is, it was a central segment of the topic. In the other text the target paragraph had a subordinate status in the macrostructure.

It was hypothesized that the target paragraph would be processed more deeply when it is a central part of the topic, and consequently its reading time would be longer. However, this was not the case: the target paragraph required an equal amount of processing time in both texts.

The method seems relatively unsophisticated, and its application is rather restricted.

2.2. Sentence reading time

A more precise way to track discourse processing in real time is to measure reading time per sentence. In practice, measurement takes place with the aid of a computer, which displays the text on a video screen one sentence at a time. The presentation is self-paced by the reader, who proceeds through the text by pressing the button which causes the next sentence to

appear on the screen. The computer simultaneously records sentence reading times, i.e., the time intervals between successive button presses.

As an example of this kind of measurement, I briefly describe a study reported by Sanford and Garrod (1978). They investigated how the semantic relation in anaphoric reference between the anaphor and the antecedent affects discourse processing. The following is an example of their materials:

(1) A bus came trundling down the hill.
(TS) The vehicle almost hit a pedestrian.
(2) A tank came trundling down the hill.
(TS) The vehicle almost hit a pedestrian.

The target sentence (TS) is identical in both contexts. Sanford and Garrod inferred that if the quality of the semantic bridge between the anaphor ('the vehicle') and the antecedents (either 'a bus' or 'a tank') controls processing, there should be a difference in target sentence reading time in these two contexts. The reason is that pragmatic knowledge should make it easier for the reader to regard 'a bus' as a class member of the concept 'vehicle' in contrast with 'a tank'. This was in fact the case. In the latter context the target sentence took longer to read than in the former context.

2.3. Word reading time

A still more precise way to monitor discourse processing on line is to measure reading time per word. The measurement is also performed using a computer. The computer displays the text one word at a time. By pressing the button the reader is able to proceed to the next word of the text. The time between two button presses is the word reading time.

An example of this kind of research is the study by Mitchell and Green (1978), which explored, among other things, the processing of the relative clause. They investigated whether it is more laborious to process the relative clause when the relative pronoun is omitted than when it is explicitly expressed, as in

(A) The tramp that the dog bit died.
(B) The tramp the dog bit died.

It was hypothesized that the clause 'the dog bit' is easier to read in sentence A where the relative pronoun is present than in sentence B where it is omitted. By applying the word reading time paradigm Mitchell and Green sought an answer for the issue.

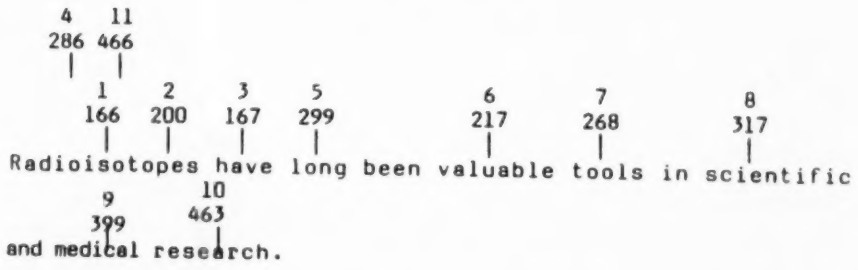
The result was that the relative clause took the same amount of time to process in both instances. It seems that for a competent reader the status of the relative clause in a sentence is clear enough even without a relative pronoun to signal it.

2.4. Eye movement recording

Recording the reader's eye movements while he is reading a text is a modern application of the old proverb which speaks of the eye mirroring the mind. In other words, the method is based on the assumption that there exists a high correlation between the reader's attention and the location of his gaze on the line of print.

Eye movements involve two things: (1) fixations, during which the eyes stay fixated on a certain word, and (2) saccades, which are short, rapid movements between fixations. The processing of text takes place during the fixations. Saccades serve the function of bringing new segments of the text into the fovea. Vision is clearest in the area of the text which falls into the fovea; furthermore, only the information located in the fovea at the moment can be processed to the semantic level. Saccades which shoot backwards in the text are called regressions.

The following example illustrates eye movement data in discourse processing. It is taken from a study by Carpenter and Just (1981).


4 11
286 466
1 2 3 5 6 7 8
166 200 167 299 217 268 317
Radioisotopes have long been valuable tools in scientific
9 10
399 463
and medical research.

The upper number expresses the order of the fixation, and the lower number gives its duration (in msec).

As an example of eye movement research I mention a study by Frazier and Rayner (1982), who investigated the ambiguities that can be created by different syntactic structures. For example:

Before the king rides his beautiful white horse is always groomed.

It takes a while for the reader to realize that 'before the king rides' forms a clause. It was the intention of the authors to find out how the processing of such ambiguities takes place. For that purpose Frazier and Rayner recorded readers' eye movements. The parsing strategy of a typical reader is to integrate new words with the clause currently being processed whenever this is possible. In the example, the last part of the sentence (i.e., '... is always groomed') cannot be integrated with the clause just completed. According to the study, this usually caused long fixations in that region, indicating that the last few words were laborious to comprehend. The long fixations were usually followed by a regression and a re-fixation in the region where the real clause boundary is located (i.e. '... rides/ his ...'). In other words, the typical reader acts as though the sentence makes up one single clause. When the last words of the sentence are encountered, he has to reconstruct the syntactic structure of the sentence. This process is reflected in the eye movements.

However, there was no uniformity of the parsing strategy adopted by subjects. Individuals varied in the way the structural ambiguities of the target sentence were resolved.

2.5. Textwindow

The "textwindow" system, developed at the University of Umeå in Sweden (Jarvella and Lundberg 1984), is a recent methodological addition to discourse processing research. The method operates as follows. The system is implemented on a computer which controls the movements of a "window" through which the reader can see segments of text on the computer screen. The window displays only a limited segment of the text (for example, a stretch of 8 characters). The window moves along the lines of the text in the same direction that the text would normally be read. New letters appear one by one from the right, causing those on the left to fall off. The reader is able to control the movement of the window by speeding it up, slowing it down,

stopping it, or reversing the run of the window in order to go backwards on the text.

An integral part of the procedure are the so-called 'probes', i.e., auditive signals that are located in relevant text segments. The reader is expected to react to these signals as fast as possible. The reaction time to the probes is used as an estimate of the mental load of the reader.

In their research program, Jarvella and Lundberg propose to use the textwindow method to investigate the following kinds of questions: How does the macrostructure of the text (a story grammar) control discourse processing? What role does pragmatic knowledge play in the immediate processing of discourse? How are references resolved?

The advantages and disadvantages of the methods presented above are currently the subject of much discussion. In most cases, comparisons seem to favour eye movement recording. There are four reasons for that:

(1) The technique makes it feasible to expose a few sentences of the text at the same time. Consequently, the reader is allowed to progress rather naturally through the text.

(2) The reader can regress to earlier parts of the text. The regressions are also recorded.

(3) Current technology allows eye movement recording which is precise enough to track processing word by word.

(4) The method does not compel the reader to fixate on every word (cf. the measure of word reading time). Instead, he may skip words as in normal reading.

However, there are some problems with the method. Firstly, the data is quite laborious to analyze. Secondly, an accurate calibration of the device is difficult to achieve.

Just, Carpenter and Woolley (1982) compared the method of measuring reading time per word with the eye-fixation paradigm, using eye movement data as the base line. They report a moderate correlation between the methods. Thus it may be concluded that the technique of measuring word reading times approaches eye movement recording as a measure of processing time expended on successive words of a text.

In the next section I propose a framework for studying the immediate processing of discourse.

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3. An outline of the process of discourse comprehension

To understand the message contained in a discourse, the reader must integrate the pieces of information inherent in the text with each other. The writer, on the other hand, should stage his message as coherently as possible. The framework I propose for discourse processing starts from this reader-writer interplay. In order to comprehend the message, the reader tries to maintain the semantic coherence between the textual propositions. In other words, the reader tries to build up a coherent semantic network of a text. Four different concepts are needed in analysing this process.

(1) The concept of semantic coherence of text, in which three aspects may be distinguished: within-sentence, referential, and topical coherence.

(2) The concept of theme-rheme structure of the text. The concept has to do with the distinction between old (theme) information and new (rheme) information (cf. Scinto 1978). Theme repeats information given in the earlier part of the text, while rheme introduces new information (for other definitions of the concept, see Enkvist 1975).

(3) The concept of subject-matter knowledge. This refers to the fact that there exist considerable individual differences in the semantic representations containing our knowledge of the world. As a consequence, individuals vary with respect to 'functional' coherence, i.e., the extent to which the semantic world explicated in a discourse resembles the semantic network of the reader (the reader's subject-matter knowledge). In other words, one reader might be more familiar with the topic discussed in a discourse than another.

(4) The concept of the purpose of reading. The reader progresses through the text differently depending on what he wishes to extract from it. Thus it makes a difference whether a text is read for leisure or whether it must be read in order to memorize as many details as possible, or to find an answer to a given question. The concept of 'reading strategy' refers to the same phenomenon, i.e., the variation in the way readers construct an internal representation of a text.

Vauras, von Wright and Kinnunen (1983) have investigated the learning strategies of high school pupils by studying recall protocols. They distinguish between a holistic and an atomistic strategy. I propose that the concept of learning strategy as employed by Vauras et al. can also be applied to the immediate processing of a discourse. The proposal is based on the assumption that the reader is constantly integrating the content of the text into an internal representation. Thus, by applying a holistic strategy the

reader tries to build up a coherent representation by finding out the main topic and integrating the other propositions of the text with it. When the reader applies an atomistic strategy, he is not bothered to construct a fully integrated representation of the text.

It may be argued that not every reader is able to smoothly adapt his reading strategy according to various purposes of reading. The argument raises the issue of metacognition. Reader's metacognitions consist of his ideas about what reading is, and what constitutes learning from text, i.e., whether it is memorizing the facts, understanding, problem solving, or something else. In spite of its importance, this issue will not be discussed further in the present connection.

By putting the above concepts together, it is possible to a propose a framework for the on-line processing of discourse. The framework of the controlling factors of discourse comprehension is given in Figure 1. It applies only to a competent reader, whose word recognition processes have become automatized. The intention is not to ignore word recognition and syntactic processes as controlling factors; they are excluded merely to keep the framework simple.

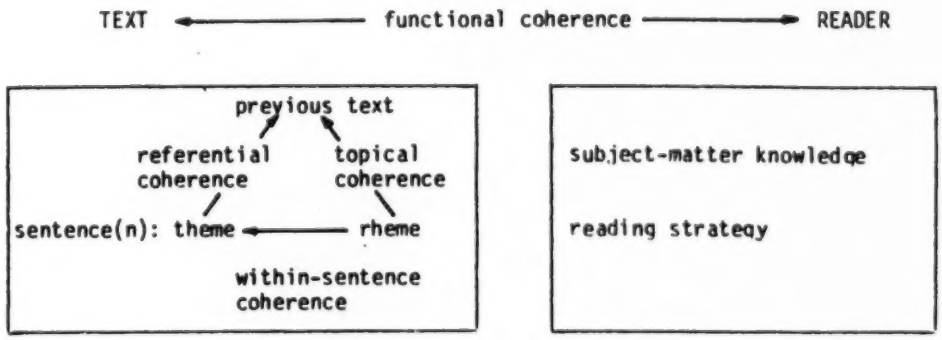

Figure 1. An outline of the controlling factors in the on-line processing of a text.

The sentence (n) is taken arbitrarily from the middle of a text being read. It consists of a theme and a rheme. The brings forward an issue which is known to the reader from the previous text. The semantic relation that exists between the theme and the previous text is called referential coherence. The rheme of the sentence (n) introduces new information about the

issue contained in the theme. The semantic relation between theme and rheme is called within-sentence coherence. The rheme is also linked with the previous text through topical coherence. The connection between the world the writer is creating through his text and the reader's semantic network is here called functional coherence.

These four types of coherence are implicit in the discourse when the reader begins to extract information from it. It depends on the reading strategy how much the reader is affected by variations in the strength of coherence. Depending on the purpose of reading, readers vary with respect to the amount of mental effort they put into maintaining coherence through reference resolution, integration of new information with given information, and the utilisation of subject-matter knowledge.

In order to specify the proposal further, I suggest some verifiable assumptions concerning coherence effects on the immediate processing of discourse. The assumptions deal with the situation where the reader applies a holistic strategy in order to process the text as completely as possible. They are all instances of the general idea that processing ease depends on how obvious the link is between a text segment and the semantic world of the previous text.

The following hypotheses can be formulated:

1. The sentence rheme is processed more fluently when it can be associated with the theme through inferences based on the textual world. When the association needs to be inferred from the external knowledge of the reader, a greater processing effort will be required. (Within-sentence coherence).

2. The sentence theme is easiest to process if a close link exists between the theme and its antecedent. That implies, for example, that processing is easier when reference is based on direct repetition, and more difficult when it is based on a substitution by a class member (cf. the bus-vehicle example above). (A qualitative aspect of referential coherence).

3. The closer the theme and its antecedent are located to each other, the easier it will be to process the theme (cf. Kintsch & van Dijk 1978). In other words, it takes less effort to integrate the theme with an antecedent that is still active in the reader's mind, compared with a situation where the antecedent is to be re-activated, i.e., recalled. (Positional distance in referential coherence).

4. If the information inherent in the rheme is semantically closely linked with the main topic of the text, it is easier to integrate the sen-

tence rheme with preceding text. (A qualitative aspect of topical coherence).

5. In the case where the rheme is not to be integrated with the topical information of a text but with a piece of thematically subordinate information, the following might be assumed: If the information with which the rheme is to be integrated is active in the reader's mind, the sentence rheme is easier to process. Information is supposed to be more active if it has appeared recently in the text. (An aspect of positional distance in topical coherence).

As was mentioned above, the assumptions are thought to apply to the case where the text is processed as fully as possible. In other words, they are unlikely to be valid if the reader employs an atomistic strategy. With respect to the atomistic strategy the following general argument might be true: The less obvious are the connections between two text segments, the less this semantic relation affects text processing. That is, when the atomistic strategy is applied, the reader does not put in extra effort to build up coherence in those sections of a text where this would be required.

As an example of a study on the qualitative aspect of topical coherence (cf. hypothesis 4 above), consider Tommola (1985). In one of his experiments, two types of text were compared, which were similar in their referential coherence but dissimilar in their topical coherence. Referential coherence was controlled by using the same referent repeatedly as sentence theme in both types of text. The dissimilarity of topical coherence was created by writing type A texts in terms of a single 'frame' or 'scenario', while the sentences of type B texts kept shifting the scenario, and thus prevented the emergence of a discourse topic.

Tommola included in both text versions an identical target sentence towards the end of the texts. In version A it explicitly expresses the topic of the text; in version B it contains just another piece of information about the topical referent. According to the fourth hypothesis (above), the rheme of the target sentence should be easier to process in text A than in text B because in version A it is semantically closely related to the topic. This should not be the case in version B. Tommola's investigation confirmed the hypothesis: the target sentence was read faster in text A than in text B.

The model outlined above reflects the modern 'Zeitgeist' of research in reading. As a result of a drastic change in research orientation in the 1970's, the focus is now on meaning and comprehension. However, the process of meaning extraction is mainly studied through recall protocols. Conse-

quently, not very much is known about how various text and reader characteristics affect the immediate semantic processing of written language. The model concentrates on this matter.

On the whole, why should we know anything about the immediate processing of discourse? I see two potentially important reasons, both of which stem from the idea of text processing as reader-text interaction. The first is associated with the reader, the second with the text.

Considering the issue from the reader's point of view, knowledge of the on-line processing of written discourse can be applied to reveal individual differences in comprehension processes. On-line studies will tell us about the effective and flexible reading strategies of competent readers. They will also aid the diagnosis of potential reasons for the difficulties that some readers experience in extracting information from text.

Investigating the role of the text in controlling the comprehension process can reveal the possible effects of various semantic structures on immediate processing. This knowledge can be taken into account, for example, in the production of learning material.

In our Department we have recently started a research project on readers' eye movements. We expect that this promising method will provide us with relevant facts about the on-line processing of discourse.

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